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CHANGES IN TRACE MOTOR ACTIVITY-FOOD CONDITIONED
REFLEXES IN WHITE RATS DUE TO THE ACTION OF SINGLE
SMALL X-RAY DOSES

By L. S. Gorsheleva

- USSR -

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CHANGES IN TRACE MOTOR ACTIVITY-FOOD CONDITIONED
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Following is the translation of an article by L. S. Gorsheleva entitled "Izmeneniye Sledovykh Dvigatel'no-Pishchevykh Uslovnykh Refleksov u Belykh Krys pri Odonokratnom Vozdeystvii Malykh Doz Rentgenovykh Luchey" (English version above) in Zhurnal Vysshey Nervnoy Deyatel'nosti (Journal of Higher Nervous Activity), Vol. 10, No. 3, Moscow, 1960, pages 449-458.⁷

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The study of the effects of small doses of ionizing radiation on the organisms of animals is of great importance. However, only isolated works are available on this subject (Livshits ¹⁴, Kotlyarevskiy, Gorsheleva and Khozak ²⁷, etc.).

In the present work we set ourselves the task of studying the effect of a single, five r dose of X-rays on the higher nervous activity of white rats. As indicators, in addition to conditioned concurrent reflexes, conditioned trace reflexes were employed, which form less readily (Gorsheleva ¹⁷), and, at the same time are more sensitive to the action of ionizing radiation. The studies were carried out on nine rats by means of the L. I. Kotlyarevskiy food-motor activity method ³⁷.

First, conditioned concurrent positive reflexes to 400 hertz (from the ZG-10-1954 sound generator; 14 volts, 50 ohms output resistance) and to the flash of a 25 watt green lamp were produced, with differentiation ⁷ between these signals and a 200 hertz tone with three decibel damping.

In order to determine more accurately the typological characteristics of the experimental animals, special studies were conducted on the basic properties of their nervous systems.

Animals 2,3,4 and 9 had the very unbalanced type of the nervous system with greater or lesser predominance of the irritation process; animals 5,7,8 were of the strong, balanced type. Animal No. 1 was of the inter-mediate strong type, and No. 6, of the intermediate weak type.

Formation of a tracer reflex was carried out on a damped trace from a flash of a 25 watt red lamp. The action of the stimulus lasted three seconds and then a pause of seven seconds followed, after which food reinforcement was administered. After the tracer reflex had been formed (i.e., the positive motor reaction appeared not during the three-second action of the stimulus in the first inhibition phase of the reflex but during the pause in the second phase of the reflex), the pause was extended to 10 seconds.

The beginning of formation of the concurrent and tracer reflexes did not differ from one another. The reinforcement of the tracer reflex, on the other hand, took place much later than that of the concurrent reflex (Table 1), which attests to the difficulty of conditioning of such reflexes in white rats. The conditioned tracer reflex was quite stable.

The dynamic pattern consisted of nine stimuli which followed one another always in the same sequence: two concurrent positive tone stimuli (tone No. 1), two concurrent light stimuli (green light) and five tracer stimuli on the trace of a flash of a 25 watt red lamp.

After the tracer reflex had been reinforced, damped and restored, a single total irradiation was carried out by means of an RUM-3 X-ray apparatus (190 kw, 15 ma, dosage 25 r per minute with one mm Al and 0.5 mm Cu filters, focal distance 60 cm, irradiation time 12 sec.). The total irradiation dose was five roentgens.

In Table 2 are cited the experimental data of rat No. 3 which has the type of nervous system strongly unbalanced by stimulation. Experiment No. 152, conducted a day before the irradiation test, showed that the tracer reflex was correctly effected during the pause, in all five combinations. The power interrelations of the conditioned concurrent stimuli were correct. Within 30 minutes following termination of the irradiation test (experiment No. 154), there were observed slight changes in the concurrent reflexes, in the form of extension of the latent period of the first conditioned reflex in the pattern, and in a mildly pronounced paradoxical phase. The conditioned tracer reflex, on the other hand, showed substantial changes of a complex nature: in two combinations, the first inhibition phase disappeared and the

Table 1
Formation of concurrent end tracer reflexes in white rats

1. No. of white rats 2. Formation of reflex to 400 hertz (tone No. 1)
3. Formation of differentiation to 200 hertz tone (tone No. 2)
4. Formation of concurrent reflex to green light
5. Formation of tracer reflex to the damped tracer from a red lamp flesh of 25 watts
6. Number of combinations of the tracer stimulus with food reinforcement during the entire period of preparation
7. Number of conditioned motor reactions during the tracer pause for the period of preparation
8. appearance 9. reinforcement 10. appearance 11. reinforcement
12. appearance 13. reinforcement 14. appearance 15. reinforcement

Rat No. 3

Table 2

Бычий датч регистратора нанесен на спектр	Установка регистрации	№ спектра	Спектральная длина в см.	Число регистрируемых спектров	Спектральная длина в см.									
					1	2	3	4	5	6	7	8	9	10
(2) До облучения:														
0 M. 20 c.	Тон № 1	671	5	10	1.0	10								
1 M. 50 c.	Тон № 1	672	5	10	0.5	30								
3 M. 40 c.	Свет. сер.	105	5	10	1.5	10								
5 M. 10 c.		106	5	10	1.5	30								
6 M. 40 c.	Св. крас.	181					25	25	24					
8 M. 20 c.	То же	182					15	15	15					
10 M. 20 c.		183					15	15	15					
12 M. 40 c.		184					30	30	30					
13 M. 40 c.		185					30	30	30					
Через 30 мин. после облучения														
(20) Спектр № 154, 22 VI 1956, Начало спектра 16 ч. 40 м.														
3 M. 20 c.	Тон № 1	675	5	10	1.0	10								
4 M. 20 c.	Тон № 1	676	5	10	0.5	15								
6 M. 30 c.	Свет. сер.	109	5	10	1.0	20								
7 M. 30 c.		110	5	10	1.0	5								
9 M.	Св. крас.	201					2/10**	25	25					
11 M. 40 c.	Свет. крас.	201					12							
12 M. 50 c.	То же	202												
14 M. 40 c.		203												
15 M. 40 c.		204												

Примечание. * Знак + означает наличие интегрального усиления радиоактивного излучения в измер. периоде. ** Прод. означает величину дифракционного усиления генерации: числитель — максимум в измер. периоде, знаменатель — интегр. период.

Table 2 continued on next page

Table 2 continued from page 47

Время засеян посадок, ч	Условия разработки	Время посадки	Общее время зарастания условий	Число периодов зарастания	Условия периода, в при 3-х сек. Абет- ризар.	Следующий дефолекс						Наш результат	
						1	2	3	4	5	6	7	
2-й день после облучения													
0 ч. 45 с.	Топ № 1	677	5	10	0,5	20							++
2 ч. 10 с.	Топ № 1	678	5	10	1,0	25							+++
3 ч. 25 с.	Свет зел.	111	5	10	1,5	20							+++
5 ч.	»	112	5	10	0,5	10							+++
6 ч. 45 с.	Св. красн. спелой	265					0,5/8 1/10	15	20				+++
8 ч. 30 с.	То же	267					1/10	12	20				+++
11 ч.	»	268											++
12 ч. 20 с.	»	269											++
13 ч.	»												
3-й день после облучения													
1 ч. 10 с.	Топ № 1	679	5	10	0,2	40							++
3 ч. 45 с.	Топ № 1	680	5	10	0,2	30							++
5 ч. 55 с.	Свет зел.	113	5	10	2,0	20							++
7 ч. 55 с.	»	114	5	10	4,9	15							++
8 ч. 20 с.	Св. красн. спелой	270					0,5/10 1,5/15 1,5/10 0,5/20	10	15	25	30		++
11 ч. 20 с.	То же	271								30	40		++
13 ч. 30 с.	»	272									40		++
15 ч. 30 с.	»	273									40		++
17 ч. 40 с.	»	274											
4-й день после облучения													
20 ч.	Опыт № 156	679	5	10	0,2	40							++
Наш опыт № 45 ч.													
1 ч. 10 с.	Топ № 1	679	5	10	0,2	40							++
3 ч. 45 с.	Топ № 1	680	5	10	0,2	30							++
5 ч. 55 с.	Свет зел.	113	5	10	2,0	20							++
7 ч. 55 с.	»	114	5	10	4,9	15							++
8 ч. 20 с.	Св. красн. спелой	270					0,5/10 1,5/15 1,5/10 0,5/20	10	15	25	30		++
11 ч. 20 с.	То же	271								30	40		++
13 ч. 30 с.	»	272									40		++
15 ч. 30 с.	»	273									40		++
17 ч. 40 с.	»	274											

Table 2 continued on next page

Table 2 continued from page 57

Время даты начала опыта	Условие раздражителя	№ опыта	Время нагрузки в сут.	Обеспеч- ность устой- чивости разд- раж- ителя в сут.	Параметры первой линии установки в зоне раздражи- теля в сут.	Параметры второй линии установки в зоне раздражи- теля в сут.	Схема условного рефлекса						Нар. усл. реф.	
							3	4	5	6	7	8	9	
31-й день после облучения														
0 м. 30 с.	Тоз № 1	691	5	10	1,9	25								+
3 м. 15 с.	Тоз № 1	682	5	20	2,0	20								+
4 м. 45 с.	Свер зел.	135	5	10	6,9	30								+
6 м. 15 с.	»	116	5	10	0,5	20								+
7 м. 30 с.	Св. красн. специал.	245					1/10	1/1	20					+++++
10 м.	То же	216					1/10	0,5/20	20					+
11 м. 30 с.	»	237					0,5/20	0,5/50	20					+
13 м.	»	218					0,5/50	1/15	16					+
14 м. 40 с.	»	234												+
32-й день после облучения														
0 м. 30 с.	Тоз № 1	703	5	10	0,5	40								+
2 м. 30 с.	Тоз № 1	704	5	10	1,0	40								+++
4 м. 30 с.	Свер зел.	137	5	10	2,0	20								+
6 м. 10 с.	»	138	5	10	3,0	30								+
7 м. 20 с.	Св. красн. специал.	260												+++
9 м. 40 с.	То же	261												+
11 м. 15 с.	»	262												+
13 м. 10 с.	»	263												+
15 м.	»	264												+
33-й день после облучения														
0 м. 30 с.	Тоз № 1	703	5	10	0,5	40								+
2 м. 30 с.	Тоз № 1	704	5	10	1,0	40								+++
4 м. 30 с.	Свер зел.	137	5	10	2,0	20								+
6 м. 10 с.	»	138	5	10	3,0	30								+
7 м. 20 с.	Св. красн. специал.	260												+++
9 м. 40 с.	То же	261												+
11 м. 15 с.	»	262												+
13 м. 10 с.	»	263												+
15 м.	»	264												+
34-й день после облучения														
0 м. 30 с.	Тоз № 1	703	5	10	0,5	40								+
2 м. 30 с.	Тоз № 1	704	5	10	1,0	40								+++
4 м. 30 с.	Свер зел.	137	5	10	2,0	20								+
6 м. 10 с.	»	138	5	10	3,0	30								+
7 м. 20 с.	Св. красн. специал.	260												+++
9 м. 40 с.	То же	261												+
11 м. 15 с.	»	262												+
13 м. 10 с.	»	263												+
15 м.	»	264												+

Примечание. * Знак + означает наличие патологического условного рефлекса на вид и звуки коры.

** Проба изменяет величину двигательной условной реакции: числитель — величина в делах, манометр, показател.

Legend for Table 2 continued on next page

Legend for Table 2 continued from page 67

1. Time lapse between stimulation and the start of the experiment
2. Conditioned stimulus
3. No. of combinations
4. Duration of isolated effect of the stimulus
5. Total duration of the effect of the stimulus, sec
6. Latent period of the conditioned reflex
7. Conditioned reflex in manometric scale points
8. Conditioned tracer reflex
9. during the pause
10. at the three-second stimulus *
11. Natural conditioned reflex *
12. Prior to irradiation
13. Experiment No. 152, 21 June 1956. Start of experiment:
10 hrs.
14. Tone No. 1
15. Tone No. 1
16. Green light
17. Red light tracer
18. same
19. 30 minutes after irradiation
20. Experiment No. 154, 22 June 1956. Start of experiment:
16 hrs 40 min
21. Tone No. 1
22. Tone No. 1
23. Green light
24. Red light tracer
25. Same
26. Notes: *Plus sign denotes the presence of a natural reflex to the sight and smell of food.
** Fraction denotes the magnitude of the conditioned motor reaction: numerator -- latent period; denominator -- magnitude in manometric scale points.
27. Second day after irradiation
28. Experiment No. 155, 23 June 1956. Start of experiment:
10:40
29. Fourth day after irradiation
30. Experiment No. 156, 25 June 1956. Start of experiment:
10 hours 45 m
31. Fifth day after irradiation
32. Experiment No. 157, 26 June 1956. Start of experiment:
10 hours 55 m
33. 25th day after irradiation
34. Experiment No. 163, 18 July 1956. Start of experiment:
10 hours 5 min.

Рис. №. 5

Table 3

Номер наго даты открытия	Установка разрушения	Номер наго даты открытия																					
1	2	3	4	5	6	7	8	9	10														
55. До облучения																							
1. M. 50 c. Тон № 1	559	5	10	1,0	30																		
4. M. 50 c. Тон № 1	560	5	10	1,0	30																		
6. M. 20 c. Цвет зел.	134	5	10	2,0	25																		
7. M. 40 c. *	132	5	10	2,0	25																		
9. M. 45 c. Свет красн. следо- вый	158					1/20																	
11. M. 20 c. То же	159					1/5																	
13. M. 10 c. *	160																						
15. M. *	161																						
16. M. 30 c. *	162																						
36. Через 14 ч. после облучения																							
1. M. 5 c. Тон № 1	561	5	10	2,0	30																		
3. M. 40 c. *	561	5	10	2,0	40																		
5. M. 20 c. Цвет зел.	133	5	10	1,5	20																		
7. M. 10 c. *	134	5	10	3,0	25																		
8. M. 55 c. Свет красн. следо- вый	163																						
10. M. 40 c. То же	164																						
12. M. 25 c. *	165																						
14. M. 20 c. *	166																						
16. M. 10 c. *	167																						

Table 3 continued on next page

Table 3 continued from page 87

4-й день, после облучения									
Онтар № 114, 16 VII 1956. Начало суток 10 ч. 30 м.									
0 ч. 50 с. Тон № 1	563	5	10	1,0	30				+
2 ч. 40 с. Тон № 1	564	5	10	0,2	30				+
4 ч. 20 с. Свет зел.	435	5	10	0,1	15				0/15
5 ч. 50 с. *	136	5	10	0	0				+
8 ч. 50 с. Свет красн. след- вой	168								
10 ч. 20 с. То же	169								
12 ч. 10 с. *	170								
15 ч. 40 с. *	172								
17 ч. 30 с. *	173								
				0,5/15					
				1/5					
					40	45	20	30	40
					18			42	50
									+
6-й день, после облучения									
Онтар № 115, 18 VII 1956. Начало суток 10 ч. 25 м.									
0 ч. 40 с. Тон № 3	567	5	10	1,5	30				+
2 ч. 25 с. Тон № 1	568	5	10	2,0	30				+
4 ч. 10 с. Свет зел.	129	5	10	2,0	20				+
5 ч. 35 с. *	140	5	10	1,0	25				+
8 ч. 5 с. Свет красн. след- вой	173								
9 ч. 40 с. То же	179								
11 ч. 25 с. *	180								
13 ч. 30 с. *	181								
15 ч. 30 с. *	182								
				2/30	28	25	40	20	25
				1/20	35	35	45	35	35
					40				+
24 ч. АЗС после облучения									
Онтар № 126, 2 VIII 1956. Начало суток 11 ч. 45 м.									
0 ч. 45 с. Тон № 1	567	5	10	2,0	25				+
2 ч. 30 с. Тон № 1	568	5	10	2,0	15				+
5 ч. 15 с. Свет зел.	159	5	10	1,5	15				+
7 ч. *	160	5	10	1,5	15				+
8 ч. 20 с. Свет красн. след- вой	218								
11 ч. 40 с. То же	219								
12 ч. 25 с. *	220								
15 ч. *	221								
17 ч. *	222								
				1/25		40			
						17			
							30	17	+
							20	25	+
							8		

Legend for table 3 shown on next page 7

Legend for Table 3, shown on page 9
column designations same as in Table 2, except as
follows: No. 35-447

35. Prior to irradiation
36. Experiment No. 112, 13 July 1956. Start of experiment:
10 hrs 35 min.
37. Second day after irradiation
38. Experiment No. 113, 14 July 1956. Start of experiment:
10 hrs 35 min.
39. Fourth day after irradiation
40. Experiment No. 114, 16 July 1956. Start of experiment:
10 hrs 30 min.
41. Sixth day after irradiation
42. Experiment No. 116, 18 July 1956. Start of experiment:
10 hrs 25 min.
43. 21st day after irradiation
44. Experiment No. 126, 2 Aug. 1956. Start of experiment:
11 hrs 15 min.

animal reacted to the stimulus and its trace; in two combinations the conditioned motor reaction disappeared in both phases of the reflex; the tracer reflex remained in only one out of the five combinations.

On the second day after irradiation (experiment №. 155), in three combinations were observed a clearly expressed leveling phase in the concurrent reflexes and a disinhibition of the first inhibition phase of the tracer reflex. On the fourth day (experiment №. 156), in four combinations, the concurrent reflexes increased, while disinhibition of the first inhibition phase of the tracer reflex was observed. The second phase was invariably retained.

On the fifth day (experiment №. 157), in all five combinations there was a marked paradoxical phase in the concurrent reflexes, and a marked increase in the latent period of the concurrent optically conditioned reflex. The emergence of an orientation reaction was observed: the rats would turn their heads in the direction of an optically conditioned stimulus (a green light); this reaction had long ago been extinguished in the process of development of conditioned reflexes. During subsequent days, the described changes were observed in greater or lesser degrees: the paradoxical phase changed into a leveling phase, and the tracer reflexes were impaired principally in the direction of disinhibition of the first phase. On the 25th day after irradiation, the nervous activity of

the animal began to become normal (experiment No. 168). The magnitude of the concurrent reflexes was also somewhat higher as compared to norm, the power interrelations of the stimuli were correct, and in the majority of combinations (four out of five) the tracer reflex corresponded to the requirements for this type of conditioned reflex.

In Table 3 are cited the data of rat No. 5 which has a strong, balanced type of nervous system. In this animal, on the second day after irradiation (experiment No. 113), no changes in conditioned reflexes were observed as compared with the initial level (experiment No. 112). The first inhibition phase of the conditioned tracer reflex was observed in four out of five combinations, whereas in normal, unirradiated animals its disinhibition was observed at times. Thus, active inhibition in this rat increased during the first stage following irradiation.

On the fourth day following irradiation (experiment No. 114) there was observed a decrease and, later, a disappearance of the conditioned concurrent reflex to the flash of a green lamp, whereas the conditioned tracer reflex remained intact in all five combinations. This disturbance should be regarded as a peculiar paradoxical phase.

On the sixth day there were observed disturbances of the tracer reflex: in three combinations there occurred a disinhibition of the first inhibition phase with preservation of the second phase, and in one combination the conditioned motor reaction was absent in both phases of the tracer reflex. Subsequently there was most frequently observed, against the background of an enhanced general excitation of the animal, a leveling and a paradoxical phase in the concurrent reflexes, and at the same time a relative preservation of the tracer reflex. On the 21st day the conditioned reflexes became normalized (experiment No. 126).

A peculiar paradoxical phase, in which the concurrent, optically conditioned reflex disappeared while the tracer reflex which had developed on the dying trace of the optical stimulus of the same intensity retained its strength, was observed also in other experimental animals (Figs. 1,2,3). It can be seen clearly that under normal conditions the concurrent and tracer reflexes to light were sufficiently strong in the animal (Fig. 1). The latent period of a conditioned concurrent reflex to green light equaled two seconds, whereas the conditioned tracer reflex appeared within 0.5 seconds after the switching-off of the stimulus; the animal at this stage during the pause made several movements which gradually increased with the

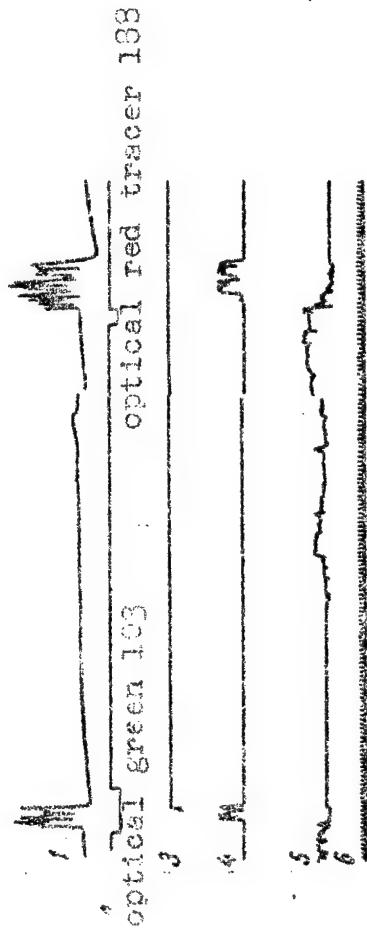


Fig. 1. Kymogram of rat No. 4. Optically conditioned concurrent and tracer reflexes in norm: 1 - specific motor conditioned reaction, 2 - stimulus, 3 - unconditioned reinforcement, 4 - movement of the feed box, 5 - the general motor reaction -- ectography, 6 - time in seconds

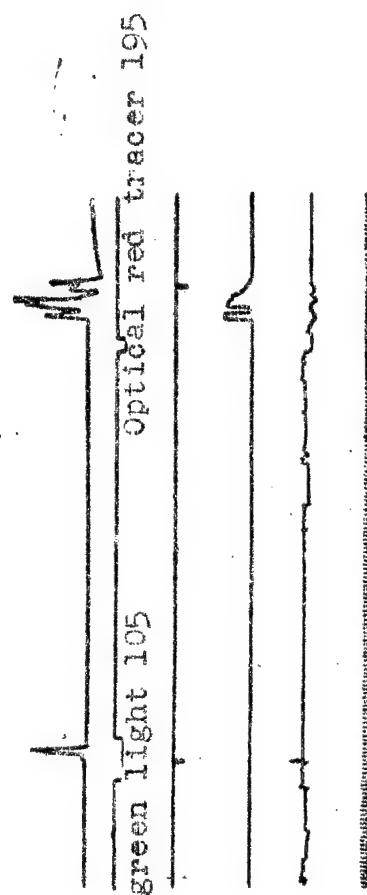


Fig. 2. Kymogram of rat No. 4 on the second day after irradiation. The designations are the same as in Fig 1.

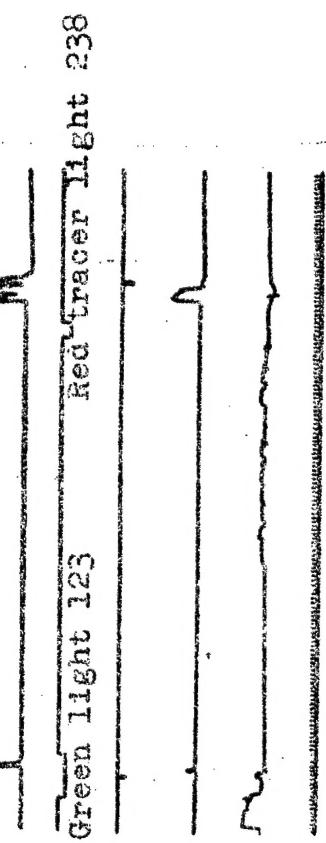


FIG. 3. Kymogram of rat No. 4 on the
19th day after irradiation.

approach to reinforcement. On the second day after irradiation (Fig. 2) the conditioned reaction to green light disappeared, but the conditioned tracer reflex remained and even acquired a more pronounced character: the motor reaction began during the fourth second of the tracer pause. The same was observed also on the 19th day after irradiation (Fig. 3).

Thus, in animals with the excitable type of nervous system (rat No. 3 and others) the disturbances appeared much earlier and lasted somewhat longer than in the representatives of the strongly balanced type (rat No. 5 and others).

In the majority of animals the disturbances of the tracer reflex, which had become much more frequent after irradiation, decreased subsequently to the initial level and even below it. The concurrent reflexes increased steadily shortly after irradiation in some animals (rats 2, 6), while in others a wave-like pattern of disturbances was observed: during the initial stage following irradiation the conditioned reflexes decreased, then increased and finally decreased again (rats 1, 4, 8). In some, on the contrary, these reflexes were higher at first, then decreased, then rose again (rats 7, 8). Various changes of the concurrent reflexes in response to sound and light were observed: in some animals the conditioned reflex to sound increased; in others this reflex showed no change but the reflex to the light stimulus increased. The undulating course of conditioned reflex changes attested, apparently, to the fact that a small X-ray dose, while exerting a stimulating effect, at the same time led to the struggle of basic cortical processes; it was not, however, as pronounced and protracted as the one observed by us following the administration of X-rays in a 50 r dose.

Conclusions

1. A single X-ray irradiation of rats with a five roentgen-dose induces mildly pronounced disturbances of power interrelations of conditioning stimuli and in the majority of cases, an accompanying increase of the conditioned reflex to light.

2. Changes in the conditioned tracer reflex are characterized basically by the impairment of its inhibitory phase, i.e., by the emergence of a conditioned motor reaction during the action of the stimulating agent: in the second phase the presence of a motor reaction during

the pause is retained.

3. There were observed cases in which, within the limits of the optical analyzer, the concurrent reflex disappeared, while the tracer reflex which had developed on a trace of a stimulus of equal force retained its full strength.

4. The conditioned reflex changes proceed in an oscillating manner during the period following irradiation, which attests to the struggle of basic neural processes in the cerebral cortex.

5. Normalization of conditioned reflexes in the majority of animals takes place between the 21st and 25th days following irradiation.

6. A certain variability in the period before the changes in the conditioned reflex is related to the typological peculiarities of the animals, and the property of steadiness of nervous processes obviously contributes to the greater stability of the organism in the presence of ionizing radiation.

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